Mineralogy and Microchemical studies of the Ferruginised section of the Upper Cretaceous Sandstone of Eastern Dahomey Basin, southwestern Nigeria

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ABSTRACT

Petrographic studies of sandstone from Abeokuta Group of Dahomey Basin, southwestern Nigeria show that the sedimentary rock consists of conglomerates, sandstone, siltstone and claystone which are ferruginized to varying degrees. Previous works on geological and geochemical data have been adequate to provide sufficient information on the mineralization potential, depositional environment facies and diagenetic changes in the clastic sediments. The current investigation therefore offer a unique approach of using mineralogical, whole-rock and microchemical methods to obtain vital information on possible mineralization, geochemical environment,diagenesis and probable source rocks of the Upper Cretaceous sediments of Dahomey basin, southwestern Nigeria.

Geological mapping of the study area was carried out around Abeokuta and Ijebu areas. Representative samples (100) of the rocks were collected from exposed sedimentary sections subjected to petrographic analysis. Polished sections were prepared from the rocks and were subjected to electron probe micro-analysis to determine the mineral chemistry. Additional mineralogical study was carried out using X-ray diffraction. Major, trace and rare-earth elements of the rocks were obtained using X-ray fluorescence.

The petrographic studies revealed quartz, muscovite and biotite flakes with potassic and plagioclase feldspars that are embedded in kaolinitic cement. Zircon, rutite, tourmaline, sillimanite and ilmenite are some of the heavy minerals present in the sandstone. Chemical data show that the clastic sediments are rich in SiO_2, Al_2O_3, Fe_2O_3 and TiO_2, which constitute about 87.43 to 95.33%. The remaining oxides, CaO, MnO, MgO, Na_2O, K_2O, and P_2O_5, Cr_2O_3, V_2O_3 are generally less than 1% each. Microchemical investigation shows that secondary enrichment of iron was accomplished through diagenetic replacement of quartz and kaolinite by limonite, which subsequently dehydrates to goethite and hematite at higher temperature.

Mineralogical and chemical composition of the sandstone most especially the presence of tourmaline, sillimanite, arkosic sand and up to 70% kaolinite, suggest granitic and gneissic origin. Also, the presence of elongated zircon grains and the angularity of the quartz grains and the accessory minerals indicate a short distance of transportation. The trace element data, the low MgO and high V/Cr ratio strongly support restricted shallow water, oxygen-rich depositional environment.

INTRODUCTION

The Upper Cretaceous sandstone of Dahomey basin have been studied by many workers including Jones and Hockey (1964), Adegoke (1969),Fayose (1970),Billman (1980), Omatsola andAdegoke (1981), Agagu (1985), Ajayi, etal., (1989) and Bolarinwa (2000) (Fig. 1). Geological and geochemical data by these workers are not detailed enough to provide sufficient information on the mineralization potential, depositional environment facies and diagenetic changes in the clastic sediments.

The current investigation therefore offer a unique approach of using mineralogical,whole-rock and microchemical methods to obtain vital information on possible mineralization, geochemical environment,diagenesis and probable source rocks of the Upper Cretaceous sediments of Dahomey basin, southwestern Nigeria.

STRATIGRAPHY

Dahomey basin was said to have been formed consequent to the opening of the South Atlantic probably during the Neocomian (Omatsola andAdegoke,1987). These workers also proposed that the basin comprises of a series of horst and graben that are filled with the Ise,Afowo and Araromi Formations jointly regarded as the Abeokuta Group.

The Ise Formation,which is the oldest clastic sedimentary rock in the basin lie uncoformably on the crystalline basement complex.It is composed of basal conglomerates overlain by coarse to medium-grained sandstones and grits interbedded with kaolinitic clays (Fig.2).A Neocomian age was assigned to the Formation by the shell-BP geologists (Agagu,1985).

The Afowo Formation is mostly composed of coarse to medium grained sandstone with thick interbedded shales, siltstones and clay.The clay component increases progressively from bottom to top.The Formation was assigned a Turorian age by Billman (1976) based on palynological assemblages.

The Araromi Formation is composed of fine to medium- grained sands at the base, overlain by shale and siltstone and marl.The shales are light grey to black,mostly marine and with light organic content (Omatsola and Adegoke,1981).The formation is said to be richly fossitiferous,bearing abundant planktonic foraminifera ostracode pollen spares (Fayose, 1970, Omatsola and Adegoke,1981).Most workers agree that the age of the formation ranged from Maastrichtian to Paleocene.

Sedimentological studies of the eastern end of the basin showed that the formations within Abeokuta Group are composed of clastic sediments of mixed provenance,probably deposited in an acidic environment. Omatsola and Adegoke (1987) also inferred a littoral or estuarine near-shore environment of deposition based on tectonic and stratigraphic studies.
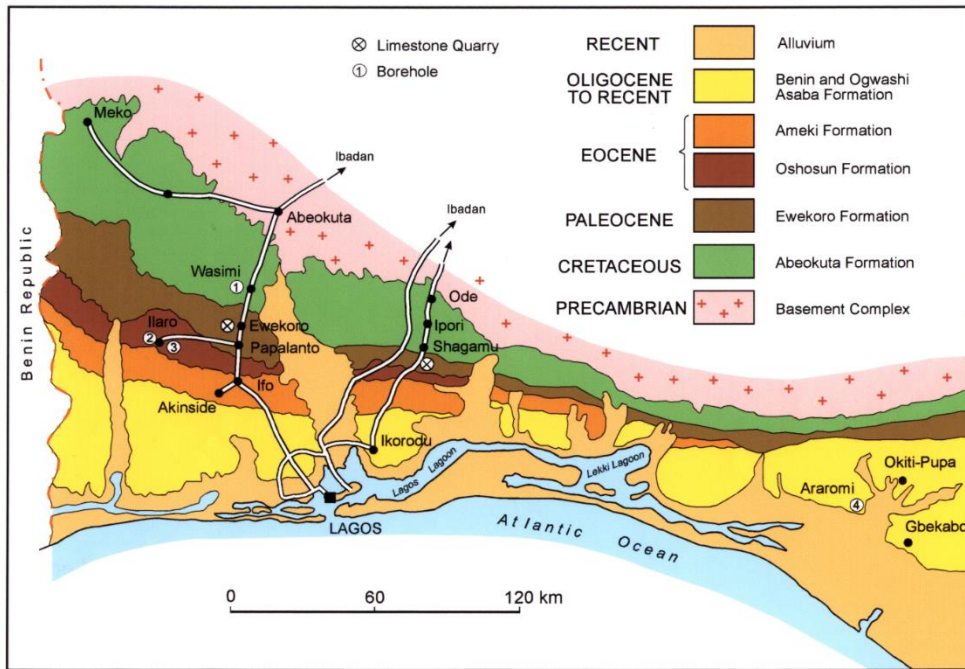
Figure 1. Geological map of the Nigeria sector of the Dahomey basin showing the location of the Araromi well in the eastern part.
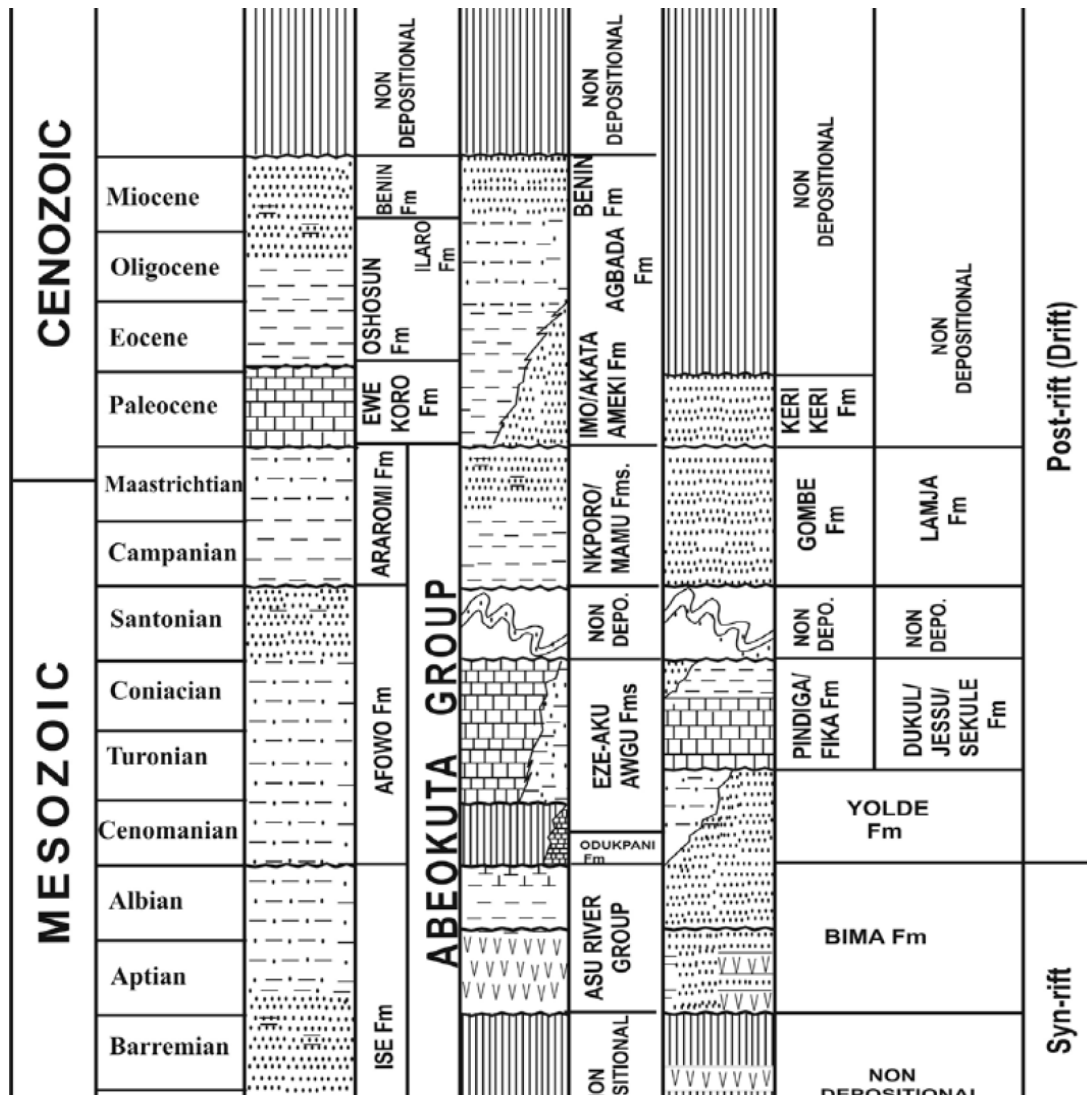
Figure 2. Generalized Stratigraphic Chart of the Eastern Dahomey and Benue Basins (Modified after Akande et al., 2004).

METHODOLOGY

Thin section preparation

Geological mapping of the study area (Fig. 2)was carried out around Abeokuta and Ijebu areas. One hundred samples were collected from exposed sedimentary sections. The clayey material and the laterite samples were collected from fresh hand-dug pits, and road-cuts. Vertical sampling interval for the clayey zone and laterite was 50cm. Thin and polished sections of the lateritic samples were prepared for petrographic examination.

X-ray diffraction analysis

X-ray diffraction (XRD) study was carried out in order to identify the mineral phases that could not be identified under the petrological microscopes with transmitted and reflected light. These include clay minerals such as kaolinite, halloysite and other secondary minerals. Their distributions within the profile are essential in the understanding of the trend of weathering.Powdered representative samples of the parent rocks (Table 2) and the overlying clay-rich and iron-rich laterites were selected for routine mineralogical analysis using Philip X-ray diffractometers, PW 1010/02 and PW 1710 BASIS models. Diffraction charts were recorded at a scanning speed of 1^0/min/cm withh a Ni-filtered Cu k α - radiation.Diffraction peaks obtained were converted from $2\square$ degrees to d spacings (A). These were compared with well established standards and interpreted with reference to Brown (1972) JCPDS (1974) and Pei-Yuan Chen (1977) table of X-ray powder diffraction patterns. Quantitative estimation of the respective minerals was also carried out by computing the peak areas of their reflection intensities (Gibbs, 1967).

Major and trace element analysis

Ten major and fifteen trace elements of twenty four representative samples of the sandstones were determined using a Philip PW1480 automated X-ray fluorescence [XRF] spectrometer. Data processing was controlled by the Philips X40 software package. Discs for both major and trace elements determination were prepared at 1100c by using spectroflux 100 (Johnson Matthey GmbH®) containing lithium tetraborate (Mucke,1999). For the determination of FeO, a titration method was used. Standard reproducibility is summarized in Table1A of Hartmann and Wedepohl(1990).H_2O- and loss on ignition(LOI) were determined gravimentrically.The precision of the analytical

deviation is +0.5% for SiO_2, +1% for most of the major elements,+2% for MnO +10ppm for Ni,Zr,Ba and Pb and+5ppm for other trace elements.

Microprobe analysis

Microprobe spot analyses of the Abeokuta were carried out using an electron probe micro-analyser, CAMERA ® SX-100, operated at 20KV and 20nA after instrument caliberation with standard minerals.Major oxide concentration, notably SiO_2,Al_2O_3,FeO,TiO_2, CaO,MgO,K_2O,Na_2O,P_2O_5, V_2O_3 and Cr_2O_3 were determined.The analytical data were recalculated to their respective mineral formulae incorporation H_2O.

Calculation of Accumulation Factor and Gain and Loss of Elements

The calculation is based on the assumptions that banded gneiss, biotite granite gneiss and porphyritic granite which constitute the major basement rock types around the sedimentary basin, are the probable progenitors of the sediments.

RESULTS AND DISCUSSION

Description of the weathering profile on the sandstone

Profiles 7,8, and 16 are located within the Abeokuta Group of Dahomey Basin (Fig. 8). The profiles are quite similar with only minor variations in the thickness of the various layers (Fig. 24). Profile 7 around Isaga and 16 near Ipara, were studied (Fig. 24). The two profiles show a thin top soil cover, underlain by 3-4m thick lateritized coarse sandstone. These reddish slightly ferruginised sandstone is underlain by brown strongly ferruginised sandstone. The ferruginised sandstone around Isaga, forms a protective cover for the underlying greyish clay. Pinkish siltstone and unferruginised coarse grained sandstone which correspond to the Ise Formation of Omatsola and Adegoke (1998), directly overlie the weathered basement rock north of Ipara town (profile 16), (Fig.24).
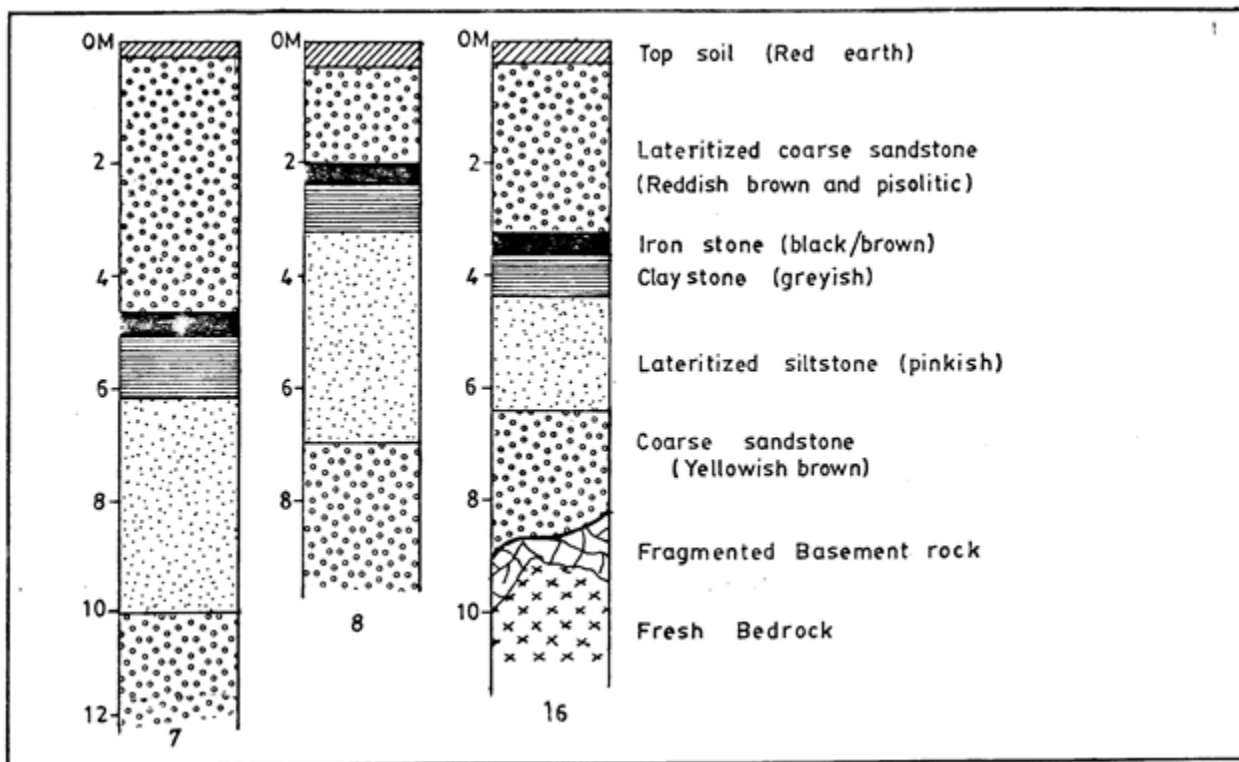
Figure . Weathering profile of the sandstone of Ise Formation Dahomey Basin.

Petrography

Petrographic studies of thin and polished sections of the sandstone of the Abeokuta Group showed that the sediments can be distinguished into three gradational categories, namely ferruginised, moderately ferruginised and strongly ferruginised sandstones.The unferruginised sandstone is made up of angular quartz grains and detrital mica in a kaolinitic cement (Fig. 3), while the strongly ferruginised variety is composed of corroded and more rounded quartz grains in a ferruginised groundmass (Fig. 4).Ferruginisation of quartz commences with limonitisation.Dehydration of limonite to goethite and ultimately hematite are noted in reflected light (Fig. 5).

Two generations of goethite are noted in strongly ferruginised sandstone, the older one, which constitute the groundmass is black in reflected light. The younger goethite,which is reddish in colour, cross-cut the older one and fractured quartz as observed in Fig. 6.The growth and development of this newly formed goethite is equal to post depositional diagenetic replacement of quartz by goethite. Zircon,

rutile,tourmaline,sillimanite and ilmenite are some of the heavy minerals present in the sandstone. Most of the sillimanite grains are corroded due to ferruginisation (Fig. 7), while the zircon and rutile tourmaline are angular or elongated (Fig. 5).

Mineralogy

  X-ray diffration charts of the unferruginised sandstone showed prominent peaks of quartz at 4.25,3.34,2.46,2.28,2.24,2.13,1.98,1.82,1.67,1.54 and1.45 Å. Kaolinite and halloysite peaks are reflected at 7.13 and Årespectively.The moderately ferruginized sandstone at the upper part of the profile (Fig. 8a) showed slight depreciation of quartz peaks, notably at 2.8,2.24,2.13,1.98,1.67 and 1.56 Å (Fig. 8b).The black to brown strongly ferruginised sandstone, termed "ironstone" is characterized by strong hematite reflections at 3.69,2.71,2.52 and2.20 Å(Fig. 8c).Subordinate goethite, kaolinite,halloysite and ilmenite peaks were also recorded on the X-ray diffractograms.

       The X-ray charts of the unferruginised sandstone at about 10m around Isaga (Profile 7), and 7m at Ipara (Profile 16) (Fig. 24) show the dominance of quartz (Fig. 25a). Prominent quartz peaks are shown at 4.25, 3.34, 2.46, 2.28, 2.24, 2.13, 1.98, 1.82, 1.67, 1.54 and 1.45Å. Kaolinite and halloysite are also present (Fig. 25 a,b, and c).The slightly ferruginised sandstone at the upper part of the profile (1-3m from the surface) (Fig. 24), is enriched in kaolinite (4.19Å) and goethite (4.18, 2.70, 2.19 and 1.56Å) (Fig. 25b).The brown strongly ferruginised sandstone, termed 'iron-rich sandstone' is characterised by strong hematite reflections at 3.69, 2.71, 2.52 and 2.20Å.Two generations of goethite observed in the polished section (Plate 17), are responsible for the variations in the reflection intensities noted on the diffractograms. The older goethite replaced kaolinite in the groundmass. Gradual dehydration of this goethite into hematite is responsible for the nearly opaque nature of the goethite under transmitted light (Plate 17). The younger goethite is reddish in colour. They are found cutting across the highly fractured sub-rounded quartz grains (Plate 17). The growth of this younger goethite is sequel to the lateritization process.Quartz peaks were recorded at 4.26, 2.46 and 2.28Å values.   Prominent kaolinite peaks are reflected at 7.13, 3.56 and 2.34Å values in the clayey zone and the laterite.
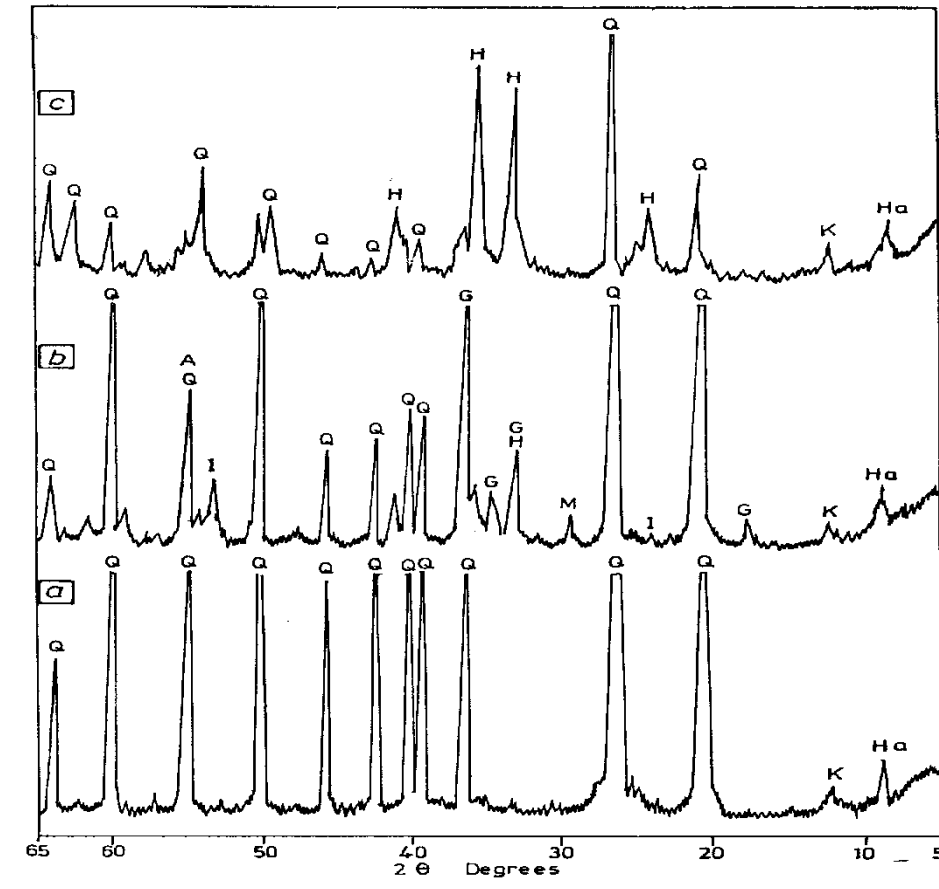
Figure . X-ray diffraction charts of the iron-rich and lateritised sandstone of Ise Formation.
(a) Unferruginised sandstone (b) Lateritised sandstone (c)Iron-rich sandstone.
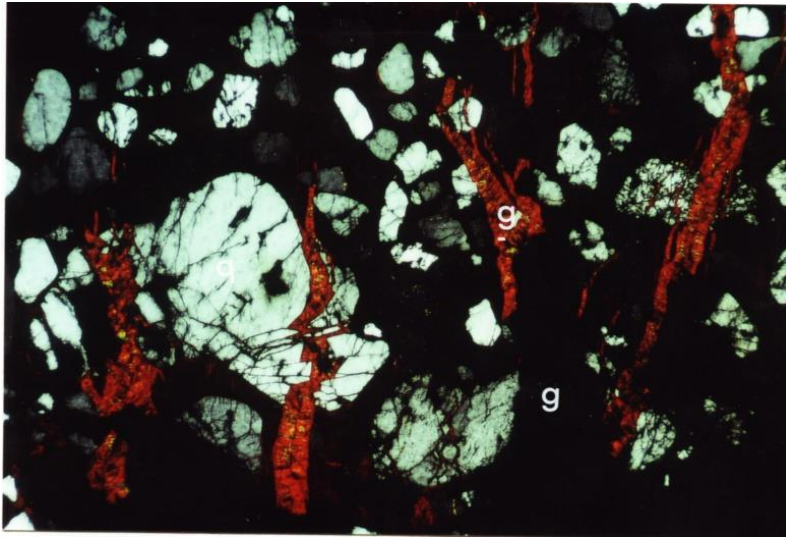
Figure . Photomicrograph of the ferruginised sandstone of Ise Formation showing corroded and fractured quartz grains floating in a matrix of iron oxides (goethite and hematite). Note the younger goethite (red) cutting across the fractured quartz. Reflected light, crossed polar, X 2.5mm, longer edge of photo is 420µm.
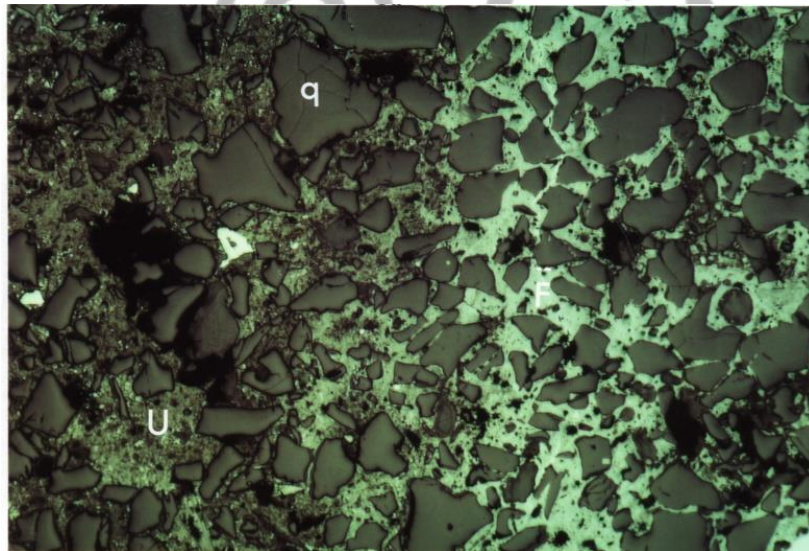
Photomicrograph showing variations in the degree of ferruginisationof sandstone
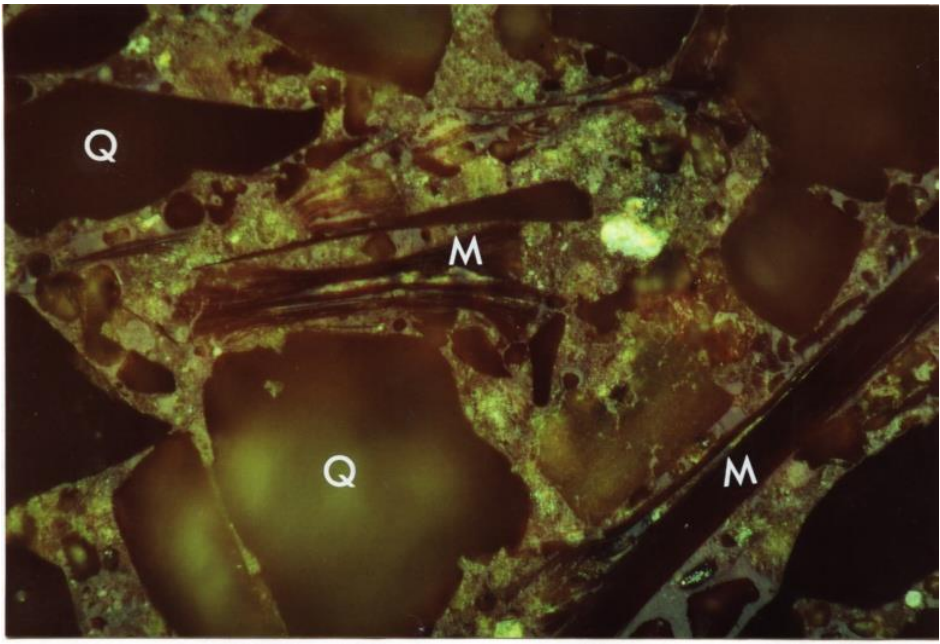
Photomicrograph of sandstone showing angular quartz and abundant detrital mica.
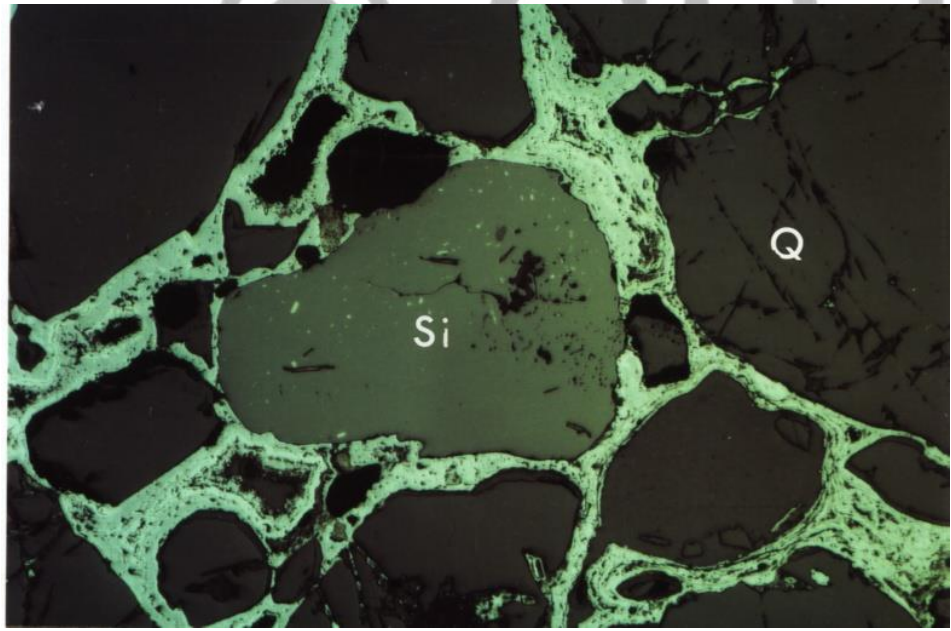
Sillimanite and quartz grains in ferruginised groundmass
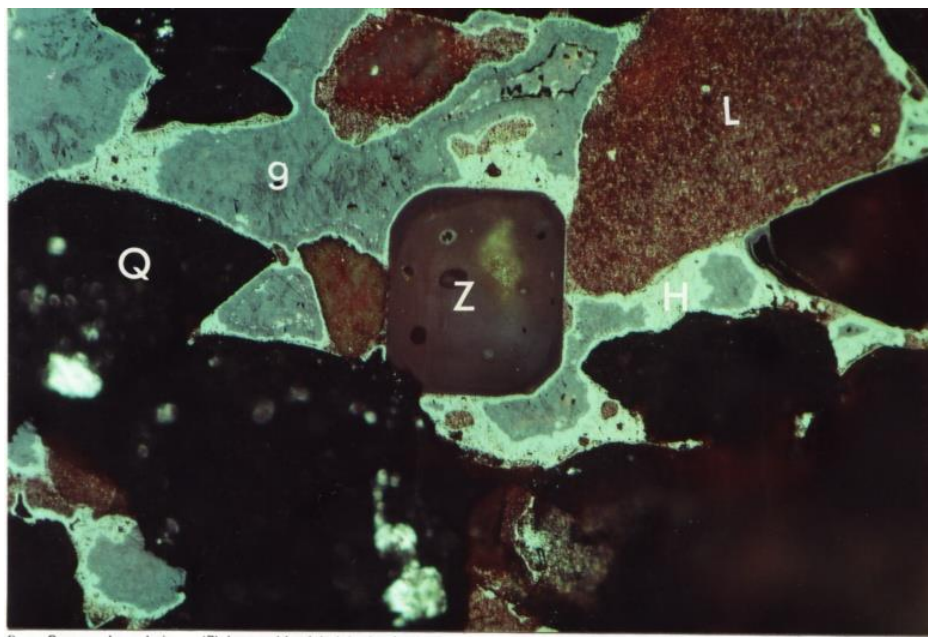
Square shaped zircon in goethite dehydrating into hematite

GEOCHEMISTRY

Whole rock geochemistry

Major and Trace Element Abundance

Chemical data of the weathering profile over sedimentary rocks exposed at Isaga, are provided in Table 11, and the variations down the profile are illustrated in Fig. 34. The dispersion trend reflects the differences in lithology from claystone at the base, to iron-rich sandstone in the middle. The iron-rich sandstone is overlain by lateritized coarse grained sandstone. The iron-rich sandstone horizon is quite distinct, with its low SiO_2 content of Ca. 19.68%, TiO_2 0.22%, Al_2O_3 14.48%, MnO 0.33%, MgO 0.06%, CaO and Na_2O 0.0.3% each and K_2O 0.09%. Fe_2O_3 value of the iron-rich sandstone is quite high (56.97%) due mainly to the presence of abundant hematite cement (Fig. 25c). Also, the P_2O_5 concentration in the iron-rich sandstone is relatively high (0.87%), compared with that of the underlying clay (0.38%) and the overlying sandstone (0.62%).

The overlying lateritized sandstone of Ise Formation (Fig. 24), is enriched in SiO_2 (66.16%) but contain low amount of in TiO_2 (0.32%), Al_2O_3 (12.74%) and Na_2O

(ca.0.13%). (Table 11, Fig. 34). The 8.68% Fe_2O_3 content is due to the presence of goethite and hematite within the sandstone. These Fe-minerals impart a reddish colouration on the lateritized sandstone.

The greyish claystone underlying the iron-rich sandstone band is composed of higher Al_2O_3 (22.13%), MgO (0.41%) and Na_2O (0.37%), than the other sections of the profile. The variations of P_2O_5 and K_2O do not follow a consistent pattern along the profile (Fig, 34). SiO_2 (59.68) and TiO_2 (0.91%) concentrations in the claystone are also high (Table 11 and Fig. 34).

Polished section of the iron-rich concretionary laterite shows the presence of altered mica and zircon in ferruginised kaolinitic groundmass (Plate 13). Alteration of primary ilmenite to leucoxene was also revealed (Plate 14).

Table 1: Average chemical composition (%) of the lateritized clastic sediments of the Ise Formation in the Abeokuta group

OXIDES	CLAYSTONE		IRON-RICH SANDSTONE		LATERITIZED SANDSTONE	
	Mean n=5	Range n=5	Mean n=5	Range n=5	Mean n=5	Range n=5
SiO_2	59.68	55.03-62.19	19-68	8.36-30.24	66.16	57.35-73.40
TiO_2	0.91	0.51-1.25	0.22	0.15-0.31	0.32	0.23-0.46
Al_2O_3	22.13	18.88-25.72	14.48	9.38-18.29	12.74	10.75-15.67
$Fe_2O_{3(t)}$	4.38	3.41-5.34	56.97	50.25-65.50	8.68	3.12-15.30
MnO	1.45	0.21-0.40	0.33	0.02-0.52	0.65	0.47-0.94
MgO	0.41	0.13-0.76	0.06	0.04-0.08	0.18	0.09-0.25
CaO	0.28	0.09-0.46	0.03	0.02.0.05	0.44	0.26-0.69
Na_2O	0.37	0.03-0.59	0.03	0.01-0.04	0.13	0.13-0.16
K_2O	0.49	0.09-0.72	0.09	0.06-0.12	0.81	0.15-1.63
P_2O_5	0.38	0.24-0.54	0.87	0.35-1.49	0.62	0.24-1.37
LOI	10.17	9.99-10.67	6.62	6.25-7.33	8.89	6.21-10.62
Total	100.65		99.38		99.62	

Trace elements (ppm)

Co	10	5-21	39	32-46	13	9-15
Cr	40	16-65	63	54-75	59	42-70
Cu	44	14-66	66	61-74	47	28-65
Ni	25	14-35	31	29-33	21	15-28
Zn	39	31-45	53	48-62	21	8-32

Silica and Alumina Ratios (%)

S.R	2.25	1.81-2.65	0.28	0.10-0.51	3.09	1.85-5.19
A.R	5.05	3.81-6.00	0.25	0.19-0.29	1.47	0.89-3.96

MgO+CaO	0.69	0.45-0.85	0.09	0.06-0.94	0.62	0.46-0.76
Na_2O+K_2O	0.86	0.39-1.24	0.12	0.07-1.79	0.94	0.26-1.05

*Full data in the Appendices (p. 225)

Abundance of trace elements within the profile does not reflect any significant enrichment. Average Co, Cr, Cu, Ni and Zn concentrations within the profile is less than 70ppm. Co is about 10ppm in the claystone. Cr is 40, 63 and 59ppm in the clayeystone, iron-rich sandstone and the lateritized sandstone respectively. Corresponding average values for Cu (44, 66 and 47ppm); Ni (25, 31 and 21ppm); and Zn (39, 53 and 21ppm) are considerably lower than the values that could be considered for ore mineralization. A general assessment of the geochemistry of the lateritized sandstone and claystone of the Ise Formation in the Abeokuta Group (Table 11), show that they are similar in composition to the weathering products of biotite granite gneiss (Table 5), and porphyritic granite (Table 9) around Abeokuta (Fig. 8). These support a widely believed opinion, that the clastic sediments of the Abeokuta Group are continental deposits, derived from the basement complex of southwestern Nigeria located into the northern part of the Dahomey Basin.

The SiO_2 - Al_2O_3 - Fe_2O_3 ternary diagram, which could be employed in estimating weathering intensity (Schellmann, 1983), may also be used to adequately illustrate relative compositional variations within the profiles and suggest the probable parent precursor. Plot of SiO_2, Al_2O_3 and Fe_2O_3 on a ternary diagram show that the lateritic material has some granitic affiliations as shown in Fig. 35. About 50% of the samples plot within the field of laterite from granite rocks. 25% plot within the field of laterite from clay or shale, while the remaining 25% plot within the field of laterite from sandstone. Detailed micro chemical studies of the mineral phases in the parent rock and the laterite are presented in the following section.

Mineral Chemistry

Result of the microprobe analyses of the lateritized sandstone of Abeokuta Group are presented in Tables 1 and 2. Iron enrichment is accompanied by depletion of SiO_2 and Al_2O_3 in the ferruginised cement of the sandstone. This is due to replacement of quartz and kaolinite by limonite and goethite which subsequently dehydrated to hematite. Microprobe studies also suggested dehydration of halloysite to kaolinite.

Accumulation factor (AF) and gain and loss (K) of elements

Accumulation factor (AF) and gain and loss (K) of elements within thelateritized sediments of the Abeokuta Group are presented in Table 33-35. It is noted that the accumulation factor (AF)

and gain and loss of elements (K) follow the same pattern with the profiles on the basement; particularly, the dispersion trend in the claystone and sandstone. SiO_2 is strongly depleted in the claystone but highly enriched in the sandstone. These may be due to the leaching of CaO, Na_2O, MgO and K_2O relative to SiO_2 in the sandstone.

Tables 33, 34 and 35 show that the AF value of Fe_2O_3 is about 2.0 in the sandstone. These correspond to gains of between 139 and 200% in the lateritic profile when compared with the basement rocks. Weathering of rocks and oxidization of iron may lead to supergene enrichment of iron minerals within the residual profile. Subsequent erosion, transportation and deposition of the iron-rich sediments in the adjoining sedimentary basin may engender the formation of ironstones (Adetunji and Kogbe, 1987). The AF of the oxides of Ti,Al, Mn and P are generally greater than 1, while the other oxides are less than 1. The data also indicate a significant gain in Cr, and Cu in the claystone, though their absolute concentrations are very low.Values of Fe_2O_3, MnO, P_2O_3 and the trace elements, Co, Cr, Cu, Ni, and Zn are higher in the iron-rich sandstone than the overlying sandstone. In the overlying sandstone, AF values of $Fe_2O_{3(t)}$, MnO, P_2O_3 Cr and Cu though lower than those of the iron-rich sandstone and the underlying claystone are also greater than 1.

CONCLUSIONS

Mineralogical and chemical analyses of the ferruginised sandstone within the clastic sediments of Abeokuta Group, show that the sandstone contains angular and sub-rounded quartz grains cemented together by goethite and hematite. The present investigation also shows that the sandstone of the Abeokuta Group, was derived from the weathering of basement rocks in the northern part of the area. This sandstone was transported via fluvial channels and deposited within the Dahomey basin in the south. Secondary enrichment of iron was accomplished through diagenetic and lateritization processes. This results in the growth of goethite that subsequently dehydrates to hematite at higher temperatures.

The lateritized sedimentary rocks on the other hand, show distinctive bedding planes and lithological contrasts, from grits at the base to claystone and ferruginised sandstone in the middle, and finally to the upper lateritic sandstone. The chemistry of the various beds is quite distinctive. Also substantial amount of smectite (ca. 10%) is present in the mineralogical assemblage of the claystone. However, the presence of tourmaline, sillimanite, mica, feldspars

and up to 70% kaolinite, suggest granitic and gneissic origin for the sandstone. Furthermore, the presence of elongated zircon grains (Poldervaart, 1955); the angularity of the quartz grains, tourmaline, sillimanite and zircon plus the presence of feldspars in the sedimentary rocks of Abeokuta Group, indicate a short distance of transportation. Thus, the lateritized sedimentary rocks are likely to have been derived from the weathering of igneous and metamorphic rocks of the crystalline basement, north of the sedimentary basin.

ACKNOWLEDGEMENTS

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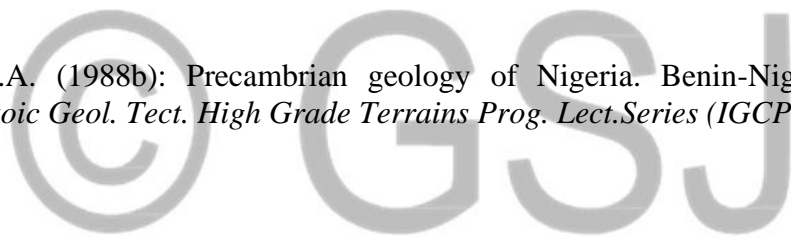
Table 1: Accumulation Factor (AF) and Gains and Losses (K) of elements in lateritised sediments of Abeokuta Group assuming banded gneiss (BG) is the parent rock

Element		Claystone				Iron - rich sandstone				Lateritized sandstone			
	BG	Clay	AF	CR	K	Sand	AF	CR	K	Sand	AF	CR	K
SiO$_2$	66.06	59.68	0.90	34.57	-31.49	19.68	0.30	17.42	-48.64	66.16	1.00	66.58	+0.52
TiO$_2$	0.28	0.91	3.25	0.48	+0.20	0.22	0.79	0.19	-0.09	0.32	1.14	0.32	+0.04
Al$_2$O$_3$	12.82	22.13	1.73	12.82	0	14.48	1.13	12.82	0	12.74	0.99	12.82	0
Fe$_2$O$_{3(t)}$	2.91	4.38	1.51	2.54	-0.37	56.97	19.58	50.43	+47.52	8.68	2.98	8.73	+5.82
MnO	0.10	1.45	14.5	0.84	+0.74	0.33	3.30	0.29	+0.91	0.65	6.50	0.65	+0.55
MgO	1.11	0.41	0.37	0.24	-0.87	0.06	0.05	0.05	-1.06	0.18	0.16	0.18	-0.93
CaO	5.33	0.28	0.05	0.16	-5.17	0.03	0.00	0.03	-5.30	0.44	0.08	0.44	-4.89
Na$_2$O	5.29	0.37	0.07	0.21	-5.08	0.03	0.00	0.03	-5.26	0.13	0.02	0.13	-5.16
K$_2$O	4.42	0.49	0.11	0.28	-4.14	0.09	0.02	0.08	-4.34	0.81	0.18	0.82	-3.60
P$_2$O$_5$	0.29	0.38	1.31	0.22	-0.07	0.87	3.00	0.77	+0.48	0.62	2.14	0.62	+0.33
Total													
Trace elements (ppm)													
Co	19.6	10.4	0.53	6.0	-13.6	39.0	1.99	34.5	+14.9	12.8	0.65	12.9	-6.7
Cr	18.2	40.2	2.21	23.3	+5.1	63.3	3.38	56.0	+37.8	59.3	3.26	59.7	+41.5
Cu	20.4	43.8	2.15	25.4	+5.0	66.3	3.25	58.7	+38.3	47.3	2.32	47.3	+27.2
Ni	22.2	25.0	1.13	14.5	-7.7	31.0	1.40	27.4	+5.2	21.0	0.95	21.1	-1.1
Zn	39.0	38.3	0.99	22.5	-16.5	53.3	1.37	47.2	+8.2	20.5	0.53	20.6	-18.4

Note that   +   represent Gain
                    -     represent Loss
                    CR   represent computed reminant

Table 2: Accumulation Factor (AF) and Gains and Losses (K) of elements in lateritized sediments of Abeokuta Group assuming biotite granite gneiss (BGG) is the parent rock.

Element		Claystone				Iron – rich sandstone				Lateritized sandstone			
	BGG	Clay	AF	CR	K	Sand	AF	CR	K	Sand	AF	CR	K
SiO_2	67.47	59.68	0.88	42.39	-25.08	19.68	0.29	21.36	-46.11	66.16	0.98	81.64	+14.17
TiO_2	0.33	0.91	2.76	0.65	+0.32	0.22	0.67	0.24	-0.09	0.32	0.97	0.39	+0.06
Al_2O_3	15.72	22.13	1.41	15.72	0	14.48	0.92	15.72	0	12.74	0.81	15.72	0
$Fe_2O_{3(t)}$	3.70	4.38	1.18	3.11	-0.59	56.97	15.40	61.85	+58.15	8.68	2.35	10.71	+7.01
MnO	0.07	1.45	20.71	1.03	+0.96	0.33	4.71	0.36	+0.29	0.65	9.29	0.80	+0.73
MgO	0.74	0.41	0.55	0.29	-0.45	0.06	0.08	0.07	-0.67	0.18	0.24	0.22	-0.52
CaO	3.43	0.28	0.08	0.20	-3.23	0.03	0.00	0.03	-3.40	0.44	0.13	0.54	-2.89
Na_2O	3.56	0.37	0.10	0.26	-3.30	0.03	0.00	0.03	-3.53	0.13	0.04	0.16	-3.40
K_2O	3.36	0.49	0.15	0.35	-3.01	0.09	0.03	0.10	-3.26	0.81	0.24	1.00	-2.36
P_2O_5	0.29	0.38	1.31	0.27	-0.02	0.87	3.00	0.94	+0.65	0.62	2.14	0.77	+0.48
Total													
Trace elements (ppm)													
Co	25.0	10.4	0.42	7.4	-17.6	39.0	1.56	42.3	+17.3	12.8	0.5	15.8	-9.2
Cr	33.8	40.2	1.19	28.6	-5.2	63.3	1.87	68.7	+34.9	59.3	1.8	73.2	+39.4
Cu	21.4	43.8	2..05	31.1	+9.7	66.3	3.10	72.0	+50.6	47.3	2..2	58.4	+37.0
Ni	20.6	25.0	1.21	17.8	-2.8	31.0	1.50	33.7	+13.1	21.0	1.0	25.9	-5.3
Zn	39.8	38.8	0.97	27.6	-12.2	53.3	1.34	57.9	+18.1	20.5	0.5	25.3	-14.5

Note that + represent Gain
- represent Loss
CR represent Computed reminant

Table 35: Accumulation Factor (AF) and Gains and Losses (K) of elements in lateritized   sedimentary rock of Abeokuta Group assuming porphyritic granite (PG) is the parent rock

Elements		Claystone				Iron – rich sandstone				Lateritized sandstone			
	PG	Clay	AF	CR	K	Sand	AF	CR	K	Sand	AF	CR	K
SiO_2	65.00	59.68	0.92	43.30	-21.70	19.68	0.30	21.83	-43.17	66.16	1.02	83.40	+18.40
TiO_2	0.76	0.91	1.20	0.66	+0.10	0.22	0.29	0.24	-0.53	0.32	0.42	0.40	-0.36
Al_2O_3	16.06	22.13	1.38	16.06	0	14.48	0.90	16.06	0	12.74	0.79	16.06	0
$Fe_2O_{3(t)}$	4.58	4.38	0.96	3.18	-1.40	56.97	12..44	63.19	+58.61	8.68	1.90	10.94	+6.36
MnO	0.08	1.45	18.13	1.05	+0.97	0.33	4.13	0.37	+0.29	0.65	8.13	0.82	+0.74
MgO	1.57	0.41	0.26	0.30	-1.27	0.06	0.04	0.07	-1.50	0.18	0.11	0.23	-1.34
CaO	2.85	0.28	0.10	0.20	-2.65	0.03	0.01	0.03	-2.82	0.44	0.15	0.55	-2.30
Na_2O	3.96	0.37	0.09	0.27	-3.69	0.03	0.00	0.03	-3.93	0.13	0.03	0.16	-3.80
K_2O	3.55	0.49	0.14	0.36	-3.19	0.09	0.03	0.10	-3.45	0.81	0.23	1.02	-2.53
P_2O_5	0.39	0.38	0.97	0.28	-0.11	0.87	2.23	0.96	+0.57	0.62	1.59	0.78	+0.39
Total													
Trace elements (ppm)													
Co	22.5	10.4	0.47	7.6	-14.6	39.0	1.76	43.3	+21.1	12.8	0.6	16.1	-6.1
Cr	24.0	40.2	1.68	29.2	+5.2	63.3	2.64	70.2	+46.2	59.3	2.5	74.8	+50.8
Cu	19.2	43.8	2..28	31.8	+12.6	66.3	3.45	73.5	+54.3	47.3	2.5	59.6	+40.4
Ni	17.0	25.0	1.47	18.1	+1.1	31.0	1.82	34.4	+17.4	21.0	1.2	26.5	+9.5
Zn	27.6	38.8	1.41	28.2	+0.6	53.3	1.93	59.1	+31.5	20.5	0.7	25.8	-1.8

*Note that   +   represent Gain

-       represent Loss

CR   represent computed reminant